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GB 2035114A
GB 2002248A
GB 1531804
GB 1312664
GB 1232231
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(71) Applicant
Maruchi Koken
Kabushiki Kaisha
75, Kozawatari-cho
Hamamatsu-shi
Shizuoka 432
Japan
(72) Inventor
Utaro Sakai
(74) Agents
Marks & Clerk
Alpha Tower
ATV Centre
Birmingham
B1 1TT

(54) Method and apparatus for oil-water separation by granulation

(57) A method and apparatus for oil-water separation utilises a coalescing element having a coalescing layer of polymeric gel applied to a porous base, the layer being water-insoluble and oil-repelling to coalesce dispersed oil. The direction of flow through the element is periodically reversed to prevent clogging, and the coalesced oil is separated from the water in a downstream settling tank.

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FIG. 1

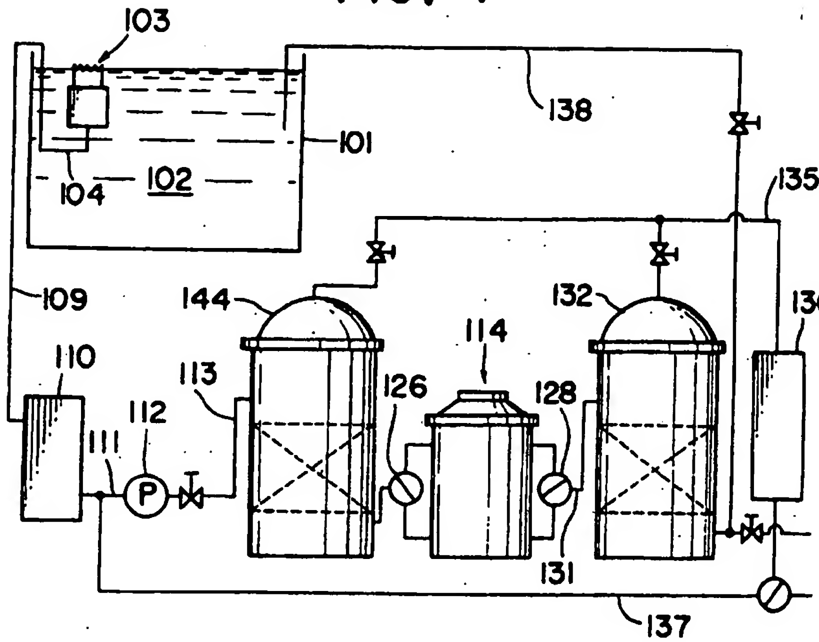

FIG. 2

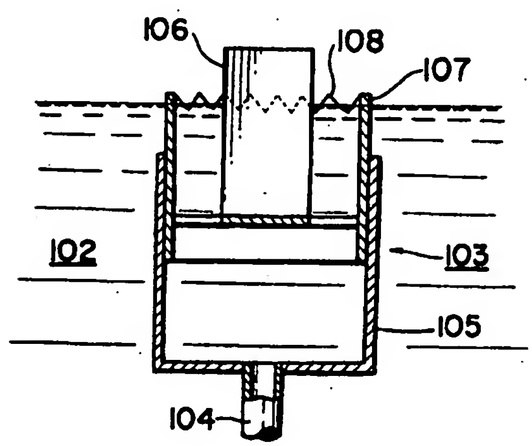

FIG. 3

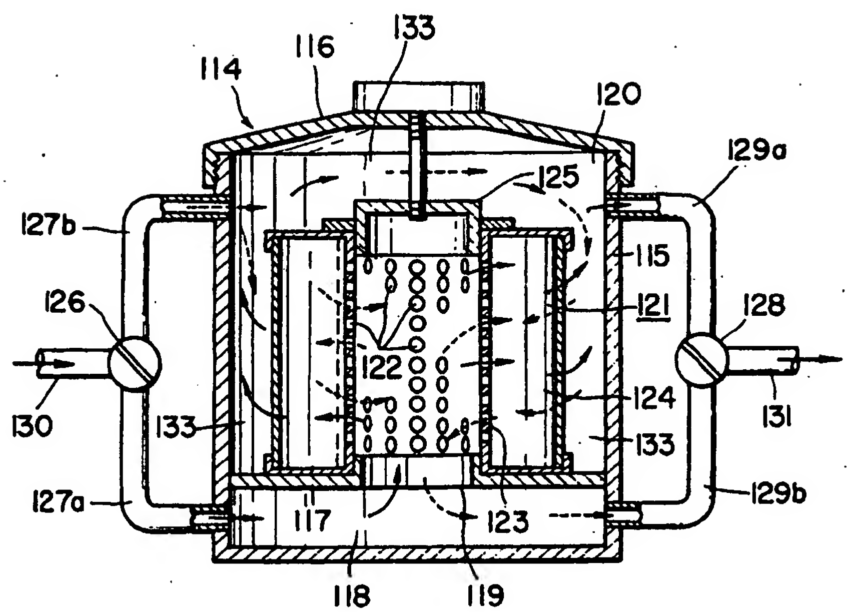
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FIG. 4

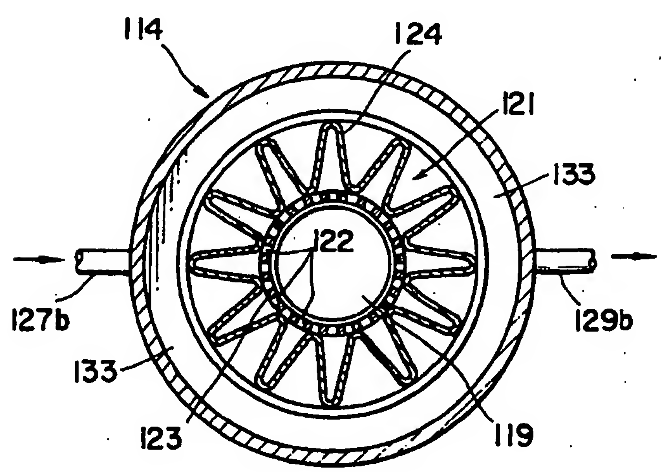
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FIG. 6

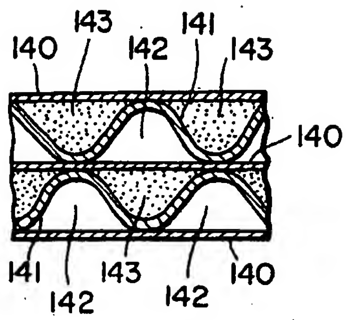

FIG. 5

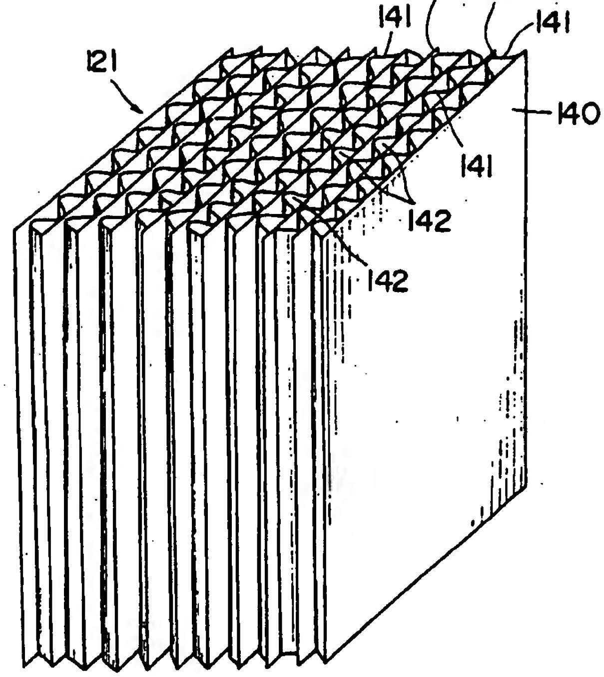

FIG. 7

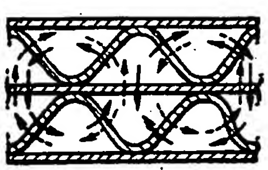

FIG. 8

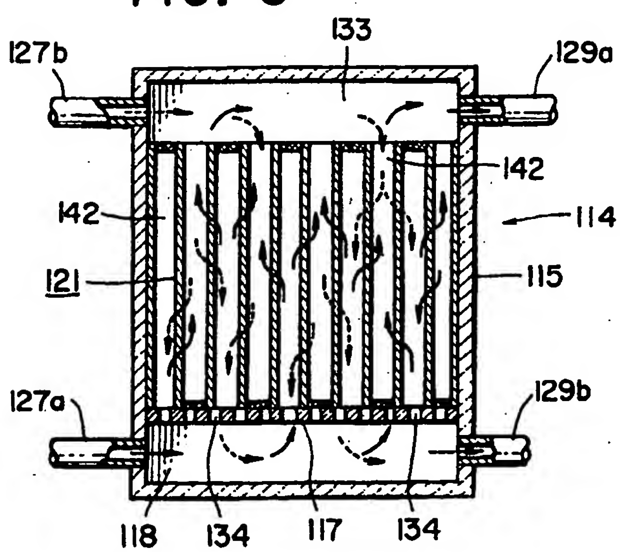

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FIG. 9

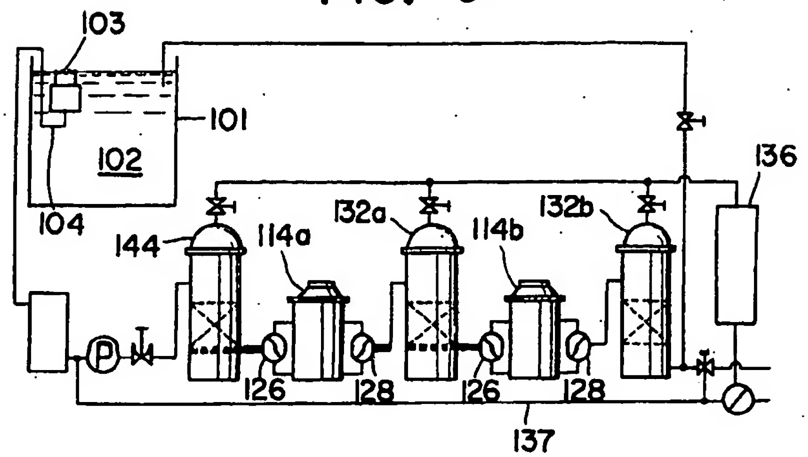

FIG. 10A FIG. 10B FIG. 10C

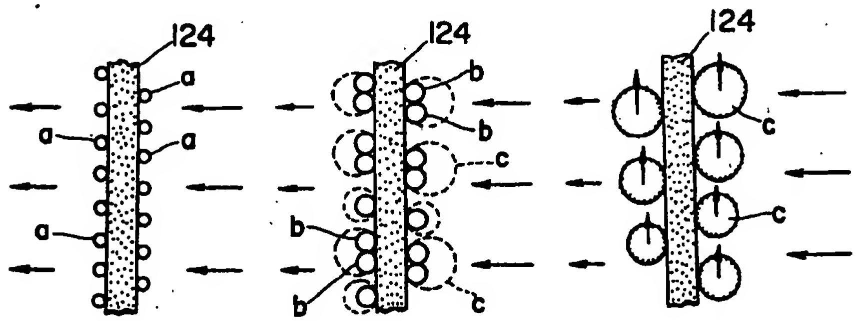

FIG. 11

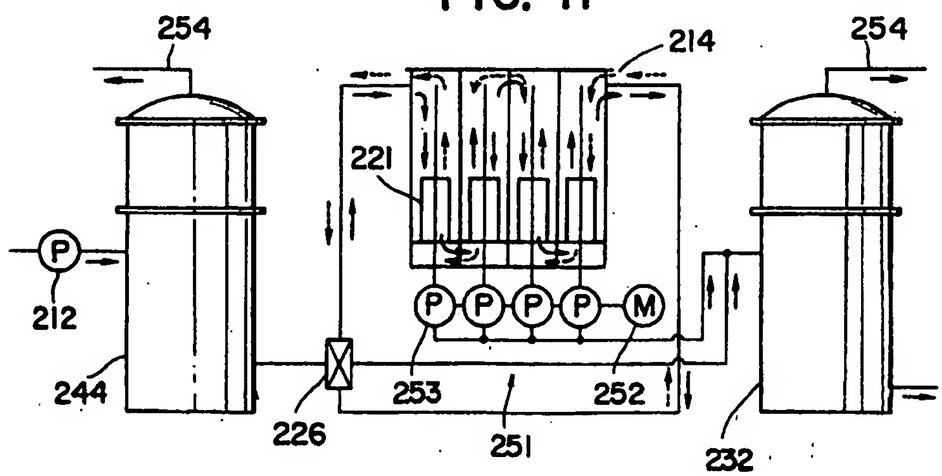

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FIG. 12

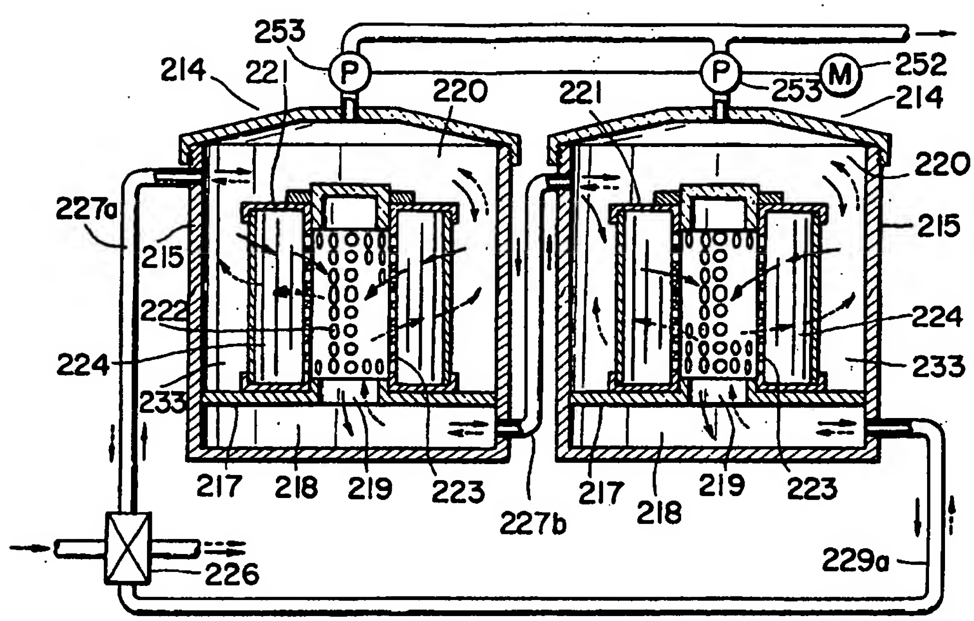

FIG. 13

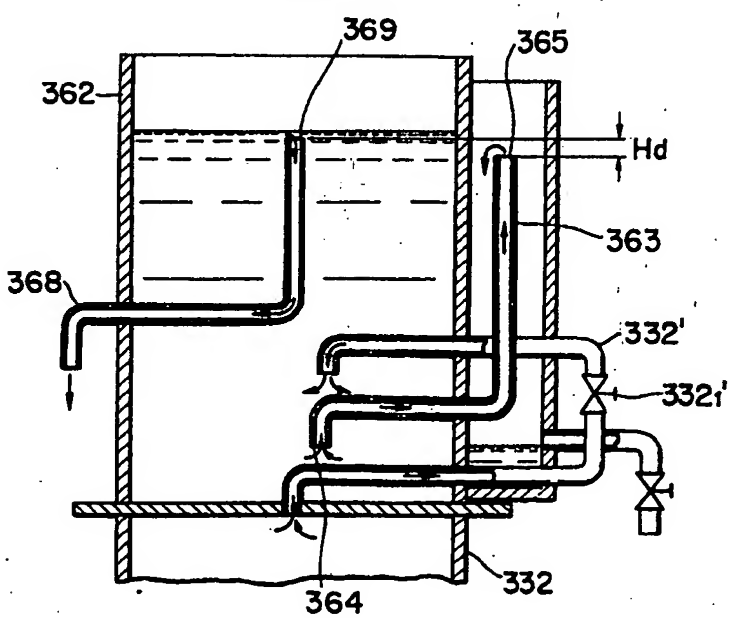

FIG. 14

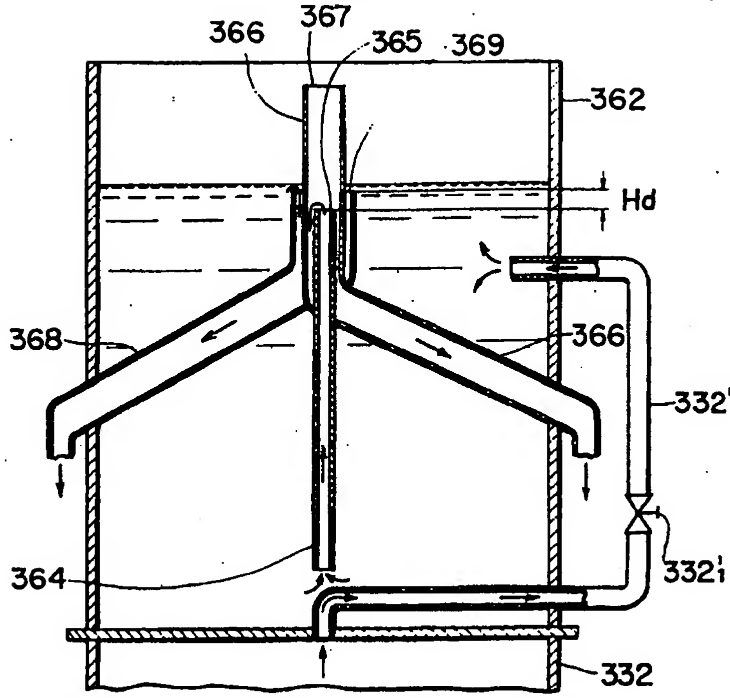
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FIG. 15

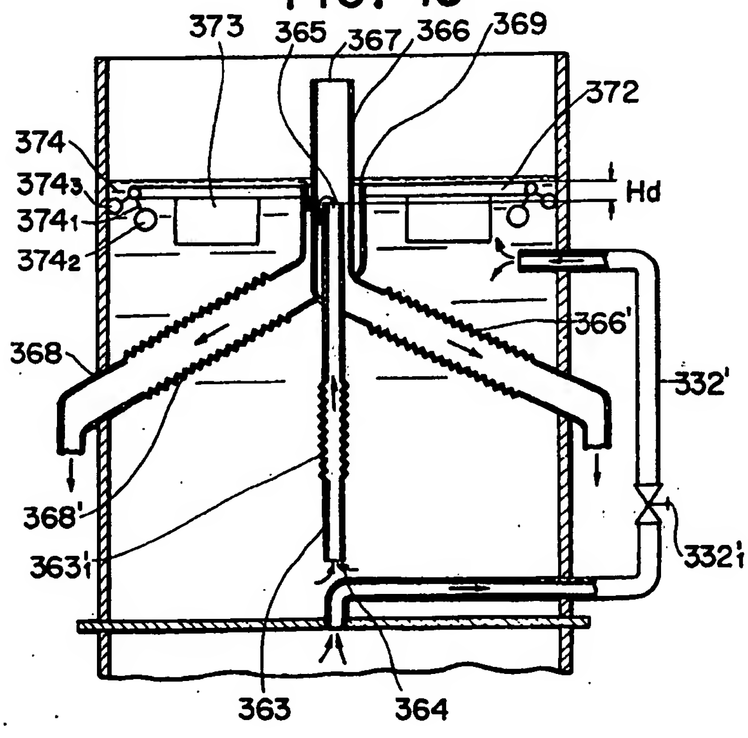
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FIG. 16

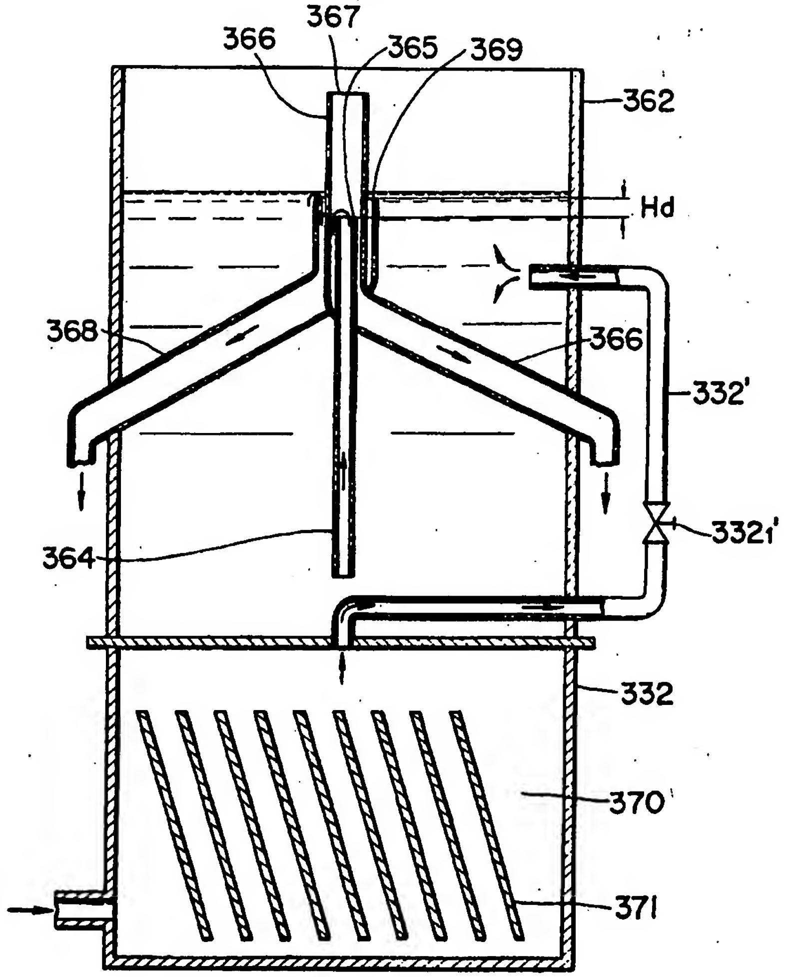

FIG. 20

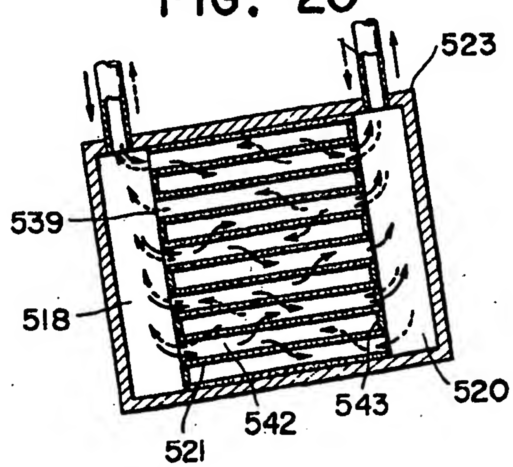

FIG. 18

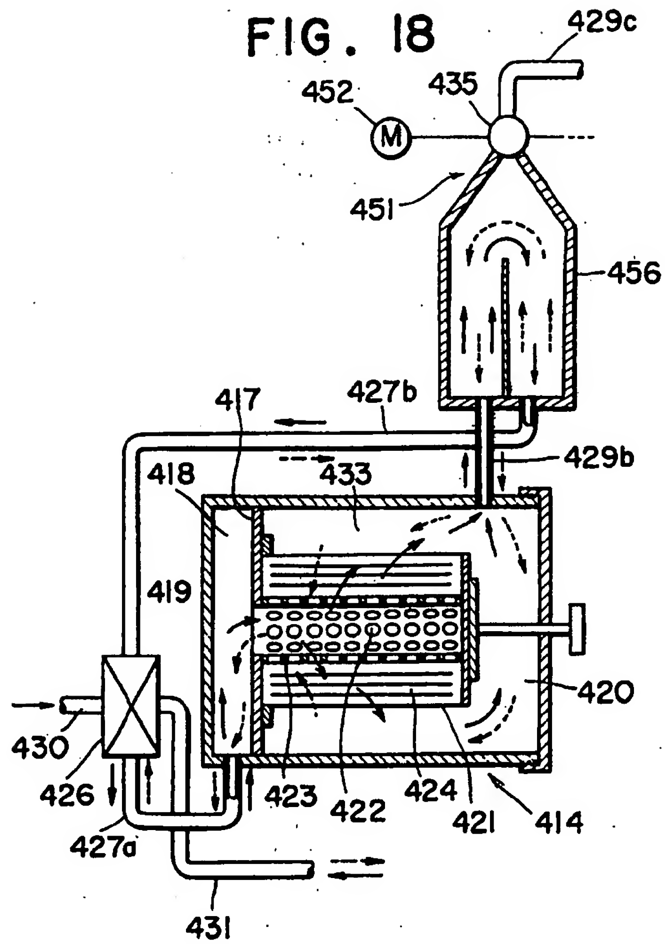
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FIG. 17

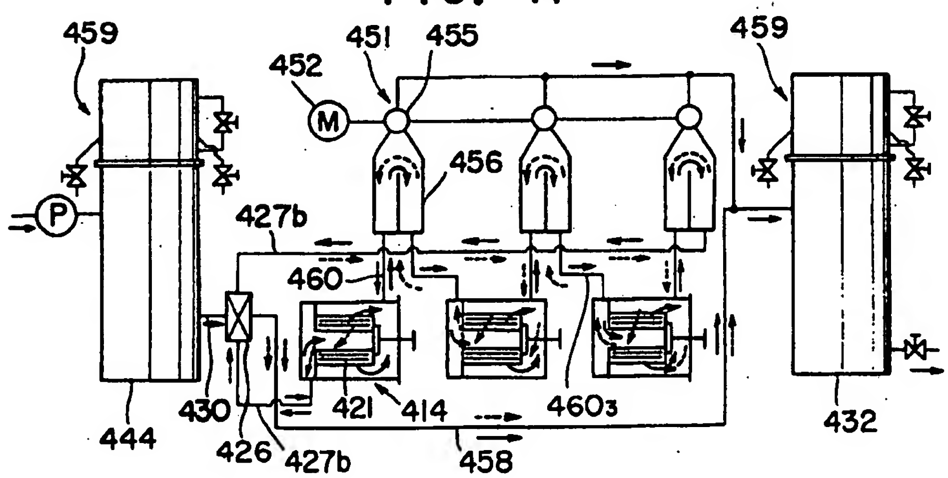
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FIG. 19

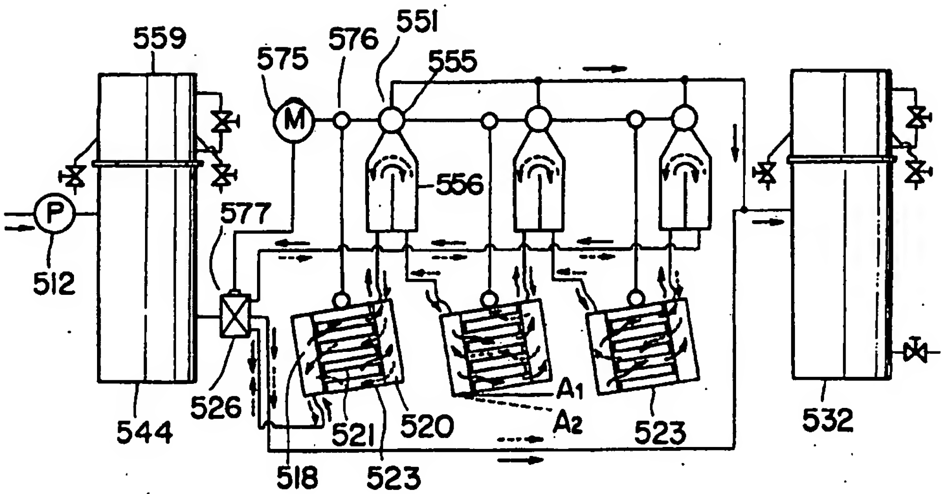
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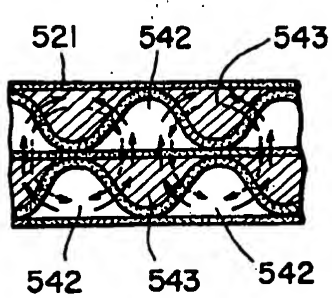
FIG. 21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SPECIFICATION

Method and apparatus for oil-water separation by granulation

This invention is related to the method and device for oil water separation by granulation of the oil contents to separate oil effectively from such oil containing water including finely divided and scattered oil or oil in an emulsified state.

Conventional methods for separating oil from oil-containing water include a gravity separation method, filtration method, adsorption method, cohesion disposition method, air floating method, microbiological process, electrolytic method, physical chemistry method and a granulation method.

The gravity method can only be applicable for oil granules, and is unsuitable for the separation of finely divided oil while the filtration method easily causes clogging, and requires large-sized equipment for the back flushing process which does still encounter difficulties in complete prevention of such clogging. The air floating method also requires a large system and makes it impossible to separate finely divided oil. The micro-biological method requires large-sized euipqment and is timeconsuming, and the electrolytic or physical chemistry method is accompanied by secondary processing, thus offering problems in connection with the size of installation involved and the procedures of processing. Further, the granulation method now available is an ideal method; which, however, cannot be applied for the range of emulsion type particles of a dimension smaller than 10μ except for precision filtration or ultrafiltration. The ultrafiltration can only be used for specific cases, because the equipment is large and expensive and the running cost is also high. On the other hand, an adsorbent, depending on its lipophilic nature, requires a high cost and a great deal of manpower for replacing it at a saturating point due to its adsorption limit being a major drawback due to impediment of oil film in the case of high oil concentration and high viscosity oil. The method of using an adsorbent for granulation of smaller than 10μ oil particle matters is impractical, and therefore this method is not adequate for the separation of emultified materials. No practical small-sized equipment for economically performing separation-by-granulation in the range of oil matters with smaller than 10μ particles is available at the present time.

SUMMARY OF THE INVENTION

The present invention is based upon recognition of this difficulties, and extensive studies have resulted in a method and apparatus to efficiently separate high concentration and/or hiah viscous oil matters or emulsified oil matter separation function and consisting mainly of a water insoluble hydrousgel layer having an oil-resisting and oil-repeling function as well as water-permeating and water-absorbing functions on the surface part of a porous material and/or the surface part of a fluid passage and using the element thus formed with this material. The invention is based on the idea of using the specific granulating element through which oil holding water is passed, alternatively changing the direction of material flow, and adding structures which may suit diversified conditions such as high concentration or high viscosity oil or emulsified oil, to allow granulation of oil in the state of smaller than 10μ particles, and thus offer a novel means of oil water separation.

The invention attains a new field of removing oil matters, of the granules having a particle size of smaller than 10μ, which had been desired by society for a long period, and is the developement in the field in which numerous research and developements project have been performed without success, and thus is of great significance in that it will enable one to cope with the requirement of 15 PPM which is required as the performance of marine use of an onboard oil water separator based on the Sea Pollution Prevention Act in accordance with the IMCO Convention.

In the granulation process of the present invention, an oil-water separating element consisting of a specific porous material is used. It is important that a water-insoluble hydrousgel layer is formed on at least one of the porous material surfaces to come in contact with oil-containing water and/or to the liquid passage surface. For example, various types of synthetic fiber, inorganic fiber, natural fiber, natural pulp, synthetic pulp, etc., are used to form a porous material, on which a specific water insoluble hydrousgel layer is formed as a granulation layer.

The types of water insoluble hydrousgel or its means of formation are not specifically limited, and can be selected and exemplified in a wider range. For example as the means of forming hydrousgel, the following are 1) A method in which an aqueous solution of a mixture of a water soluble monomer such as acrylamide, acrylic calcium or acrylic soda with methylene bisacrylamide or N-methylolacrylamide, added with a polymerization catalyst such as ammonium persulfate or persulfate soda, potassium persulfate, hydrogen per oxide and a condensation catalyst such as ammonium chloride or mono ammonium phosphate, is prepared, and such a solution is adhered to the porous sheet by means of immersion, painting, spraying, etc., and is then dried at a temperature of about 80–110°C to effect polycondensation, thereby obtaining a water-insoluble hydrous-

of applying an aqueous solution of a material having a plus (+) ion charge (compounds having a cation charge such as pyridine or quatenary ammonium group) on a porous sheet, and applying an aqueous solution of a material having a negative (−) charge (compounds having an anion charge such as carboxyl group or sulfone group) on the sheet, whereby such materials are ionically coupled to each other at the surface or in the interial of sheet to form a so-called ion complex; (3) a method in which a gel compound is obtained by the coupling reaction of a water soluble polymeric substance such as carboxymethyl cellulose, polyphosphate, polyphosphoric acid salt, polyacrylic soda with a polyvalent metallic salt such as magnesium sulfate or calcium chloride, i.e. by previously applying an aqueous solution of polyvalent metallic salt on a porous sheet by way of immersion, coating, spraying, etc., then adding an aqueous solution of the above stated water soluble polymetric compound capable of being crosslinked with a metal, followed by intermediary action of polyvalent metallic ions; (4) a method for making natural or synthetic hydrophilic polymeric substance insoluble without losing its water absorbing characteristics, i.e. wherein a porous sheet is previously applied with a crosslinker such as chrome alum, potash alum, formalin, zinc chloride, boric acid, magnesium chloride, etc., and a gel compound is formed through a chemical crosslinking reaction by adding a gelatinizer such as gelatine, polyvinyl alcohol, alginic acid, mannan, or cellulose compound; and (5) a method of utilizing a material which absorbs water and swells to form a water insoluble hydrousgel, for example, a method of applying a crosslinked polyethylene oxide (soluble in an organic solvent) to a porous sheet by way of immersion, coating, or spraying or a method of adding lower-substituted carboxymethylated cellulose or polyvinyl fiber by mix spinning or mix weaving.

In the present invention, the layer which is insoluble in water and capable of absorbing water as mentioned above is applied on the surface of a porous sheet and/or the surface of a liquid passage to come in contact with oil-containing water; however, of importance is that there is no lowering of the porosity of the porous sheet filter after formation of the water-absorbing gel layer. In the selection of one or a mixture of filter materials (having a sufficient porosity), the porosity must be taken into account. When the amount of water transmitted is too large, the efficiency of oil-water separation drops with increases in the amount of water leached out. When the amount of water transmitted is too small, on the other hand, the rate of oil-water separation drops sharply.

In the present invention it is desirable to provide a further process for enhancing and maintaining the effect of the oil separation function such as an oil-repelling function, oil-collecting function, granulating ability for oil drops, as well as forming the water-absorbing gel. For example, a lipophilic agent such as a fluorine compound or chrome fluorine compound, lipophilic agent or oil collecting agent such as stearic acid compound, silicone base compound, wax compound, surface, tension-reducing agent or oil collecting agent such as a high alkyl alcohol, silicone alkylene oxide or fluorine surfactant are added to the water insoluble hydrousgel layer. Alternatively the porous sheet will be treated with such an agent by coating, immersing or spraying before or after forming the water absorbing gel. The porous sheet may have a lipophilic portion formed with the water absorbing gel layer. For example, an oil-separating effect by oil collection, growth and separation can be improved by constructing a filter material by means of a mixed making or mixed spinning of polyolefin fiber or pulp, synthetic fiber of glass fiber.

In this invention any material having characteristics sufficient for use as a filter, i.e. material having water permeability, water resistance, pressure resistance and durability, can be widely used as the porous sheet without any restriction. For example, board, non-woven fabric, paper or foam seet can be used. Non-woven materials such as paper or non-woven fabric made mainly of cellulose fiber such as cotton, rayon or acetyl cellulose are used after being given the characteristics of water resistance, pressure resistance, durability, etc., by reinforcing treatment such as described in the Office Gazzette as No. 659628. With a porous sheet made of woven fabric such as filter cloth, the aforesaid reinforcement can be omitted as the material itself has characteristics required for filtering, such as water resistance, pressure resistance; however, the reinforcement process is preferably applied. Use may be made of other methods such as those comprising the steps of making a non-woven porous sheet by forming a mixture of heat melting synthetic pulp (polyolefin, nylon, polystyrene, etc.), and applying synthetic pulp thereto by a heating process, or applying a crosslinking compound such as urea—formalin condensate, melamine—formalin condensate, epichlorohydrin compound, methylol group-containing compound, divinyl sulfone compound, etc., to the porous sheet by coating, immersing, spraying, etc., so that the filter function will not be lost.

On the other hand, the porous sheet of the present invention can be made of synthetic fiber material such as polyethylene, polypropylene, phenoric resin thread, polyester, polyamide or of inorganic fibers such as glass fiber, ceramic fibre, asbestos, or of a composite of such various fiber mixtures.

In a preferred embodiment of the invention

use is made of a fixing process in order that specific water absorbing gel layer will not separate from the porous sheet. For example, this process is implemented by using a cation fixing agent such as polyethylene imine, epichlorhydrin polyamide, dicianidiamido—formalin condensate, or an anion fixing agent such as urea—formalin condensate, melamine—formalin condensate in dependence upon the type of the porous sheet, and applying it on the porous sheet by way of coating, immersing, spraying before and after formation of the gel layer or impregnating it into the gel layer.

The element for the embodiment of the present invention is advantageously of small size. For example, the porous materials may simply be arranged in multistages. However, it is most preferable to make structures having a number of small passages formed by corrugated cardboard flutes or similar structure of the porous material.

BRIEF DESCRIPTION OF THE DRAWINGS

A more complete appreciation of the invention and many of the attendant advantages thereof will be readily obtained as the same becomes better understood by reference to the following detailed description when considered in connection with the accompanying drawings, wherein:

Figure 1 is a general view of the oil holding water processing system in one embodiment of the method of the present invention;

Figure 2 is a sectional side view of the suction port equipment in the system;

Figure 3 is a sectional side view of a first example of an element;

Figure 4 is a sectional plan of Fig. 3;

Figure 5 is a perspective view of a second example of the element used in this invention;

Figure 6 is a plan view illustrating one end of the element shown in Fig. 5;

Figure 7 is a plan view of the element of Fig. 5 explaining the condition of oil containing water-permeating the element;

Figure 8 is a sectional side view indicating another embodiment of the element;

Figure 9 is a schematic drawing indicating another embodiment of implementation of the present invention;

Figures 10(a), (b) and (c) are views explaining the process of granulation to form a larger lump of oil in the oil containing water through the element.

Figure 11 shows a further embodiment of the present invention;

Figure 12 shows one example of the element used in the embodiment of Fig. 11;

Figure 13 is a side view of a conventional oil-water separator;

Figures 14–16 are side views of oil-water separators used in the apparatus of the invention;

Figure 17 shows a still further embodiment of the invention;

Figure 18 is a side view of the element used in the embodiment of Fig. 18;

Figure 19 shows a still further embodiment of the invention;

Figure 20 is a side view of the element used in the embodiment of Fig. 19; and

Figure 21 is a plan view illustrating one end of the element of Fig. 20.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Fig. 1 is a general outline of the embodiment of this invention, in which numeral 101 is a crude water tank to store oil containing water. The oil containing water 102 is taken out through a suction port equipment 103. The suction port equipment 103 is constructed as shown in Fig. 2, by which outer cylinder 105 is joined with take-out tube 104 to the bottom and fixed at an appropriate place below the liquid level in the crude water tank 101, inside this outer cylinder 105, is a weir cylinder 107 having a float 106 is inserted to move freely and vertically such that the brim of the weir cylinder is positioned slightly below the liquid level. The weir cylinder 107 provides communication with the take-out tube 104. This brim of the weir cylinder 107 may be formed so as to be flat, but uneveness 108 of a saw edge type or notch type is preferable. The suction port equipment 103 enables automatic absorption of the high oil concentration part at the surface of the oil containing water 102 in the crude water tank 101, and is constructed to allow oil contain water 102 to flow in from the upper end of the weir cylinder 107 which moves in accordance with changes of the height of the liquid surface by way of the function of a float.

The purpose of suction port equipment 103 is to move the suction port in accordance with the change of the fluid level so that the oil containing water will be continuously sucked in from the high oil concentrated surface part, as the fluid level of the crude water tank varies about 200 to 300 mm up and down when items to be washed are put into or removed from the crude water tank 101.

The take-out tube 104 of the suction port equipment 103 passes through pipe 109 outside the crude water tank 101 and is connected to a strainer 110. The strainer is mainly provided to remove foreign elements in the oil containing water, and the strainer 110 is selected from conventional known products.

The oil containing water from the strainer 110 passes through a pipe 111, a pump 112 and a pipe 113 and enters into a first floating separation tank 144. High concentration oil and high viscous oil are removed here. As for the first floating separation tank, are providing

used. The oil containing water is sent to the next granulation equipment 114 in the form of a reduced oil charge, after much of the high concentration and high viscosity oil is removed as the oil containing water passes through the first floating separation tank 144. If there is no possibility in yielding high concentration or high viscosity oil in the oil containing water, the first floating separation tank 144 can be eliminated and the oil containing water from the pump 112 may directly be sent to the granulation equipment 114.

Fig. 3 is a longitudinal sectional side view of the granulation equipment 114, and Fig. 4 is a cross-sectional plan view of the same equipment. Equipment 114 has a middle floor 117 at the bottom of a cylindrical case 115 to form a passage chamber 118. An opening 119 is formed in the center portion of the middle floor and an element chamber 120 is formed over the middle floor 117, with chamber 120 accommodating the granulation element 121 which has porous material 124 on which specific granulation layer having water permeable and absorbing function is formed. The structure of element 121 is the same as that of a conventional element. That is, around cylinder 123, which is formed with many through holes 122, at the center part thereof, porous material 124 is formed in a zigzag shape and the cylinder 123 is positioned over the opening 119 of the middle floor, and the upper end of the case 115 is covered with a lid 116 to which an element holder 125 is installed to fix element 121. Also, an appropriately wide space is formed to the peripheral side and upper portion of the element 121.

Further in this apparatus, each end of the flow in branch tube 127a and 127b which is separated through a changeover valve 126 and is attached and opened to flow to the inside of element chamber 120 and the passage chamber 118, and similarly each end of the flow out tube 129a and 129b, which is split from changeover valve 128, is opened to flow outside, opposing the opening of the flow-in tubes 127a, and 127b. The flow-in side changeover valve 126 is attached to a pipe line 130 from the pump 112, and the flow-out side changeover valve 128 is attached to a pipe line 131 which leads to a floating separation tank 132.

In equipment 114, oil holding water from the pipe line 130 flows into the equipment 114 either from branch tube 127a or 127b according to the operation of the changeover valve 128, such that flow out from the upper branch tube 129a occurs only when flow occurs in from the lower branch tube 127a, and on the contrary flows out from the lower branch tube 129b only while flow occurs in through the upper branch tube 127b. By virtue of the operation of the changeover valves 126 and 128, the oil holding water passing in from lower branch tube 127a flows as shown by a solid arrow from the passage chamber 118 through the opening 119, the holes 122 of the cylinder 123, permeating through the material 124, through the branch tube 129a and exits to pipe line 131. Also, when changeover valves 126 and 128 are shifted to pass the oil holding water from the branch tube 127b, it flows as shown by the dotted arrow mark to permeate through the material 124 from the outer side and enter into the cylinder 123, through the opening 119, the passage chamber 118 and lower branch pipe 129b and passes out to the piping. In other words, by changing the flow-in and flow-out position with respect to the equipment 114 by the operation of changeover valves 126 and 128, the direction of oil holding water permeating through the element 121 is reversed.

When oil holding water flows into the equipment 114 and permeates through the element 121, not only the granulated oil content but also finely divided and scattered oil of the size less than 10μ is positively caught and collected by the oil separation function of the action of element material 124 which is formed with a granulation layer providing a water permeating and absorbing function, and the oil collection grows into a coarse oil particle which can automatically float, and is separated out due to this floating characteristic as well as due to the oil separation function of the gel layer on the porous material 124. Moreover, by permeating through the element, by virtue of its special function, emulsion type oil drop which were hitherto considered unable to be separated, grows from a coarse particle to a coarse sized lump which can be removed.

Oil holding water thus permeating through the element 121 is removed as water and a coarse oil particle through branch tube 129a or 129b and the pipe line into the next stage floating separation tank 132.

Now, in the oil holding water many types of admixtures (SS) such as suspension and small dust are generally included. Therefore, the element will be choked so as to cause reduction of function during servicing. In many conventional systems, operation of the equipment was stopped in such case to wash the element so as to recover its function, and this resulted in a reduction of processing ability to a marked degree. This invention has solved this deficiency splendidly, so as to enable the equipment to be operated continuously without stopping accompanied with cleaning effect of the element.

The equipment can be operated with the manipulation of changeover valves 126 and 128 to divert the inflow between the branch tubes 127a and 127b, and the outflow between the branch tubes 129a and 129b. The

manipulation of these changeover valves causes the flow of oil holding water to be reversed as shown by solid line arrow mark and dotted line arrow mark in Fig. 3. This reversal flow causes SS attached to the face opposite to the flow of the porous material 124 to be removed. Moreover coarse particulates, and enlarged oil drops which are attached to this surface will also be removed and separated by this reversal of flow. Both sides of the element serve equally for granulation and enlargement of oil drops notwithstanding the direction of the flow of oil holding water.

The manipulation of the changeover valves 126 and 128 may be performed manually after an established time, after collection of an established amount, or by the increase of feed water pressure; however, automatic operation can be adopted by interlocking the operation of the valves 126 and 128 with a timer, a flow meter, or a feed water pressure gage. In the so-called reverse washing operation which will be performed by reversing the direction of flow of oil holding water, removal of oil particles from the elements is effective as well as is the pressure loss at one element so as to be as low as about 0.1–0.4 kg/cm², which results in a good water permeating efficiency and therefore allows water feeding under low pressure.

Generally in oil water separation, oil will be finely divided to reduce coarse particulation separation as the feeding water pressure increases; however, in this invention a lower pressure can be used as stated before, so as to prevent oil from being finely divided, and result in a synergistic effect for better coarse particulation of oil particles.

Fig. 5 through Fig. 8 indicates another example of the embodiment of the element and the granulation equipment, in this example corrugated cardboard flute structures having many fine tubular passages are used as the element as shown in Fig. 5.

This element 121 is made similar to the element 124 of the above example; plain boards 140, which are made of porous material formed with a granulation layer having a water permeable and water absorbing function and the corrugated boards 141 of the same material are placed alternately to form laminated structure, making many fine tubular passages 142, being positioned between those plain board and the corrugated board. Either the top or the bottom end of the respective fine tubular passages 142 formed as noted above are plugged by elements 143 as shown in Fig. 6, to allow each neighboring passage to be oppositely plugged. Consequently, the oil holding water coming into each passage 142 is caused to flow only by permeating either plain board 140 or corrugated board 141. The plugging 143 can be pressed adhesion using adhesive, or filling the opening with adhesive filler, etc.

Fig. 8 indicates granulation equipment accomodating the elements as shown in above Fig. 5, in which many through holes 134 are formed in the middle floor 117 located on the bottom of the cylindrical case 115, the elements 121 are placed on this middle floor 117, and a cavity 133 is formed above the elements 121, branch tubes 127a, 127b, and 129a, 129b are respectively opened to the passage chamber 118 and the cavity 133. The oil containing water flowing in from either branch tube 127a or 127b enters into the passage 142, the ends of which are opened respectively as shown by the solid line arrow mark or the dotted line arrow mark, enters into the neighboring passage permeating the plain board 140 or the corrugated board 141, enters into the passage chamber 118 or the cavity 133 through the opened end of the passage, and flows through the branch tube 129a or 129b.

The structure of the flute type element 121 as shown by Fig. 5 through Fig. 7 is more efficient than the conventional common structure as shown in Fig. 3 and Fig. 4, and their application as shown in Fig. 8 is easier to make smaller equipment, and the use of this type is more practical. Specially such smaller configuration is indispensable in the case of limited installation space as in the case of marine application, and this invention can comply with such a stringent installation condition.

As stated above referring to Fig. 1, oil containing water is treated such that coarse particles are separated and float in the water through operation of granulation equipment 114 and flows into the next floating separation tank 132 through the pipe line 131.

The floating separation tank 132 can be of any known type. In this example, physically enlarged oil particles naturally float to the upper portion of the tank 132 by means of their difference in reaction to gravity, and are taken into an oil collecting cylinder 136 from the upper part of the tank 132 through a pipe 135 or discharged outside. At this stage, the treated water is led to the crude water tank 101 or discharged outside.

The above example indicates a basic oil water separation system as a unit of the granulation equipment; however, multistage water flow by air alternate series installation of the plurality of the granulating equipment and floating separation tanks may in many cases lead to effective results according to the condensation and viscosity of the oil included. With such a multistage water flow system, coarse particulated oil is removed prior to the next coarsing process, interim resistance of oil in the next process can positively be reduced and the oil separation rate can be improved.

flow system is desirable as far as the installation area permits it.

Fig. 9 indicates the outline of this multistage water flow system, in which oil holding water from the crude oil tank 101 passes through the first floating separation tank 144, then passes through a water flow system of serially and multistaged granulation equipment and flaoting separation tanks in the order of the first granulation equipment 114a—the first floating separation tank 132a—the second granulation equipment 114b—the second floating separation tank 132b, and feeds almost completely separated oil into the oil collecting cylinder 136. In this case the oil from the upper part of the second floating separation tank 132b is flown into the oil collecting cylinder 136 automatically or manually, and the processed water from the lower part of the second floating separation tank 132b flows into the crude water tank 101 for the case of circulating use, and is otherwise discharged.

This system is not only adequate for the efficient transient processing of oil containing water, but also demonstrates an especially superior effect in the processing of emulsified finely divided oil containing water including oil particles smaller than 1μ by the effect of a surface active element, which could not be attained by conventional technique. For example, it has been experimentally confirmed that the water containing 250,000 ppm of light oil can be processed to less than 5 ppm under the test specification of ship's equipment in accordance with the IMCO-Convention, and that 5 ppm determined as the limit for industrial waste water for environmental protection can perfectly be attained.

This invention has especially novel features in permitting separation of not only the finely divided oil but also the emulsified oil content, because of the formation of the specific layer mainly consists of water insoluble hydrousgel layer having an oil water separation function as well as an oil resisting and oil repelling function.

Althrough the theoretical base for this is not sufficiently clear, the following reason can easily be surmised from its structural characteristics. The abstract of the oil separation process is shown in Fig. 10. When oil containing water permeaters through the element material 124 from one side, oil particles or emulsified oil particles in the oil holding water attach lightly onto the surface of the material 124 by its oil resisting and oil repelling function to form multiple granulated oil *a*, and when oil in the continuously inflowing oil containing water are formed as particles in the other part, some of them are caught in the granulated oil particle *a*, and grow to become a large oil particle *b*, by and by those grown oil particles *b*, *b*, will contact each other to the dotted line. This enlarged oil lump *c* will be separated from the surface of the material 126 by the repelling action of the material 124, and is transformed to have a floating condition due to the self floating function in the oil holding water as shown by the arrow mark and begins to float. And many of these growing oil particles or lumps easily adsorb SS, and can removes SS as well as oil from the oil holding water.

Another special feature of this invention is that, becuase of its desirable SS removing performance stated above, the strainer 110 placed prior to enter in the granulation equipment 114 is not required to have such a fine straining mesh to collect even fine SS. For the requirement to catch relatively large SS only, a strainer of above 30 to 40 mesh will be sufficient for the purpose.

The conventional method requires use of as fine a mesh as possible to catch and remove SS there, and oil drops are finely divided there because of the effect of pressure caused by passing the fine strainer, and the fine oil particles were thus emulsified to make removal of oil more difficult. On the contrary, by this invention pressure resistance of the strainer is lower, does not cuase emulsification and results in easier oil separation in the coarse particulating equipment 114, which enables almost perfect removal of emulsified oil which is prevented from being further emulsified. Further, high pressure water feeding for high viscosity oil to a strainer causes a deficiency in intensifying emulsification; however, the invention does not require high pressure water feeding equipment, does not cause any impediment thereof, and because of simultaneous discharge of SS entrapped in the oil particle at the surface of the element, results in efficient removal of SS simultaneously with oil separation.

Referring to Fig. 11, there is shown a flow chart of the mthod according to the present invention, wherein reference numeral 221 stands for an element, 214 a granulator including element 221, 251 an oil extractor equipped with a motor 252 and an extracting pump 253, 226 a main changeover valve, 212 a main pump, 244 a first floating tank, 232 a second floating tank, and 254 an oil matter discharge pipe.

A feed of oil-containing water is passed through pre-treatment device such as a strainer and the like, and pumped into the granulator having element 221 via the pump 212, the first floating tank 224 and the main changeover valve 226.

Fig. 12 is a longitudinal section of the granulator 214. The granulator 214 includes a granulation cylinder 215 provided at its lower portion with a middle flooring 217 to form a passage chamber 218. An opening 219 is formed in the central portion of the

ment chamber 220. The chamber 220 is incorporated with the granulation element including a porous material 224 on which is applied a specific granulation layer capable of absorbing and transmitting water therethrough. The element 221 may be identical in construction with the widely available element. More specifically, the porous material 124 treated as mentioned above is corniced around a cylindrical member 223 having a number of through holes 222, 222 at the center. The member 223 is positioned in alignment with the opening 219 in the flooring 217 and fixed thereon. There is then left an appropriate space 233 around and above the element 221.

The granulator 214 is also formed with inlet (outlet) pipes 227a, 229a in communication with the changeover valve 226 and with a pipe 227b for connecting a plurality of cylinders 215 with each other, if applied. It is noted that, where the granulation cylinder 215 is of a single stage arrangement, the process liquid returns from the connecting pipe 227b to the changeover valve 226. The oil-containing water fed by the main pump 212 is passed through the changeover valve 226 as indicated by the solid lines in Fig. 12. enters the element chamber 220, permeates through the porous material 224, and enters an element chamber 220 of the next granulation cylinder 215 from the outlet pipe 229a via the opening 219 in the middle flooring 217. A material flow similar to that in the first cylinder 215 is also formed in the second cylinder 215. This flow is fed to the changeover valve 226 via the element chamber 220 and the element 221, from which it is supplied into the second floating tank 232.

As the oil-containing water enters the granulator 214 and permeates through the element 221, a dispersion with fine oil granules having a size of at most 10 microns being dispersed, to say nothing of the granulated oil matter, is positively collected owing to the oil-absorbing function under the action of the porous material 224 on which is applied the specific layer capable of separating oil from water due to its water-transmitting and -absorbing properties. The thus collected oil matter grows into a larger oil granule which is spontaneously floatable, and is separated out due to floatage as well as the oil-separating function provided by the (oil-repelling) gel layer on the porous material 224. With the element 221 having such a unique function, it has now been found that oil drops in the emulsion form can grow into a larger granule and be separated off, despite the fact that they have been considered unable to be isolated.

The oil matter reaching the top of granulator 214 shown in Fig. 11 is positively extracted as occasion arises or at regular intervals by the extractor 251, and is fed into the second floating tank 232. Especially where a plurality of granulator 214 are arranged in multistage manner, an extractor is provided for each granulator. With this arrangement, the oil matter having a high oil content and/or a high oil concentration serves to reduce a load applied on the surface layer of element 221 in the next granulator 214 in the course of granulation, thus making marked improvements in the efficiency and durability of granulators 214.

It has been found that the provision of extractors results in considerable reductions in the number of granulators 2.

The concentrated oil matter thus fed to the second floating tank 232 is further fed to an oil-water separator which automatically separate the oil from the water by use of different levels resulted from the different specific gravities.

A typical conventional separator by specific gravity is illustrated in Fig. 13. A water reservoir 362 into which is introduced a feed of oil-containing water is provided at its lower portion with an inlet portion 364 for a water discharge pipe 363 which, extends vertically from the inlet portion 364 and terminates in an outlet portion 365 positioned outside of the reservoir 362. The reservoir 362 is also provided at its inner upper portion with an inlet port 369 for an oil discharge pipe 368 terminating in an outlet port 369 located outside of the reservoir 362. The inlet port 369 for the oil discharge pipe is then positioned at a level higher than the outlet port 365 for the water discharge pipe. Such a level difference is shown at H_d.

On the other hand, an oil matter of high concentrations built up in the upper portion of a loating tank 332 is slowly pumped into the reservoir 362 by adjustment of a valve 332′ mounted on an oil-ascending pipe. Only the oil matter of high concentrations is separated from the oil-containing water in the reservoir 362, and automatically forms an oil layer in the upper portion thereof. Upon the oil layer reaching at its uppermost surface the inlet portion 369 for the oil discharge pipe, only the oil matter is automatically discharged through the inlet port 369 to the outside. The treated water free from oil matters of high concentrations enters from the inlet portion 364 provided in the bottom of water reservoir 364 into the water discharge pipe 363, and is discharged through the outlet port 365 to the outside. It is noted that, since there is a level difference H_d between the inlet port 369 for the oil discharge pipe and the outlet port 365 for the water discharge pipe, only the treated water is automatically discharged with no removal of the oil matters until the thickness of the oil layer amounts to H_d. No automatic discharge of only the oil matters takes place

has a thickness amounting to H_d. The oil level is always maintained at a level higher than the water level due to the difference in specific gravity between the oil and water parts. The prior art oil-water separator illustrated is characterized in that, by making use of such a level difference H_d, an oil matter can be removed through an oil discharge pipe only after an oil layer is surely formed, having a thickness amounting to at least H_d.

The conventional arrangement of Fig. 13, although functioning satisfactorily in a stationary state, has a disadvantage in that it cannot follow a tilting movement. That is to say, a level difference H_d varies in an inclined state with resultant discharge of a part water through the inlet port 369 for the oil discharge pipe, since there is a distance between the outlet port 365 for the water discharge pipe and the inlet port 369.

The following apparatus provides an oil-water separator which is free from the above-mentioned drawbacks, and can sufficiently be used in, for example, shipping experiencing tilting and rolling movements.

Referring to Fig. 14 which is a sectional view of one embodiment of the present invention, a water reservoir 362 is provided at its lower portion with an inlet 364 for a water discharge pipe 366, and at its central upper portion with an outlet 365 for the water discharge pipe, which is positioned vertically. Above the outlet 365, there is an opening space 367 which is covered with a water discharge pipe sleeve 366 positioned at a level sufficiently higher than a liquid level. The water treated is discharged through the pipe 366. An inlet port 369 for an oil discharge pipe is provided around the sleeve 366. The oil discharge pipe inlet 369 is positioned at a level higher than the water discharge pipe outlet 365 (with a level difference H_d), whereby an oil matter is separeted from oil-containing water and constantly discharged in an automated manner. The arrangement of Fig. 14 is different from that of Fig. 13 in the following points. In accordance with the Fig. 13 embodiment, the water discharge pipe inlet 365 and the oil discharge pipe inlet 369 are located at the center portion of the water reservoir and positioned in proximity to each other with a level difference H_d, and the opening 367 in the water discharge pipe sleeve 366 applied on the port 365 is positioned at a level sufficiently higher than a liquid level. With such an arrangement, there is no virtural variation in the level difference H_d between the outlet port 365 and the inlet port 367, even in an inclined state. Consequently, only an oil matter can be discharge through the oil discharge pipe inlet 367, even when the arrangement is out of the perpendicular. There is also no possibility that an oil matter may enter the water discharge [illegible] opening 367 in the sleeve 366 is positioned considerably above a liquid level. Namely, the separator of the present invention is not affected by tilting or rolling, and can constantly effect automated separation of oil matters from oil-containing water, and discharge of the oil matters and the treated water. As shown in Fig. 14, the angular disposition of the oil discharge pipe 368 and the water discharge pipe 366 assures satisfactory discharge of oil and water even in a state where the separator is out of the perpendicular. The device explained in the foregoing is suited for a ship which is subjected to vibration or tilt. In order to prevent waves from being created on the liquid surfaces, oil-resistant and net-shaped structure may be provided below the surface of the liquid shown in Fig. 14. In such an example, it is preferable that the structure has a predetermined thickness and extend from the water discharge pipe 366 and the oil discharge pipe inlet 369 to cover the entire liquid surface such as to meet the minimum tilting requirement of 25 degrees in all directions stipulated in the Ocean Pollution Prevention Law according to the IMCO Convention.

Another example of oil-water separator will be explained referring to Fig. 15. In a water reservoir 362, a water discharge pipe 366, an oil discharge pipe 368 and a water discharge pipe sleeve 366 are at their middle portions with flexible pipe members 363', 368' and 366'. A plurality of floating rod 372 extend sideways from the pipe 368, and are provided with floats 373. The floating rod 372 are also formed at the distal ends with float guides 374 which serve to maintain a water discharge pipe outlet 365 and an oil discharge pipe inlet 369 at the center of reservoir 362, when the separator is out of the perpendicular. In the embodiment as illustrated in Fig. 16, the float guide comprises a radially extending L-shaped lever 369 pivotable around its apex, a balance weight 374_2 attached to its inside and a guide 374_3 attached to its outer end.

With such an arrangement, the water discharge pipe outlet 365 and the oil discharge pipe inlet 369 can follow a tilt of the associated vessel, i.e., an inclination of the water reservoir. The water discharge pipe outlet 365 and the oil discharge pipe inlet 369 are maintained at the central position of the water reservoir 362 under that action of the guides 374. That is to say, when a tilt is given to the reservoir 362 to form the liquid surface into an ellipitical shape, the balance weight 374_2 in correspondence with the major axis thereof descends and forces out the guide 374_3, so that the outlet 365 and the inlet 369 are always maintained at the central position of the reservoir 362. The embodiment of Fig. 14 can sufficiently follow a tilt of the reservoir [illegible]

369 has sufficiently small diameter relative to the reservoir 362. When it is required to increase the diameter of the inlet 369 for attachment to a large-sized vessel, however, there is a risk that a portion of water below the oil layer may possibly enter the oil discharge pipe inlet 369 of Fig. 14 by an inclination thereof. The example of Fig. 15 is characterized in that it can completely follow a tilt of the liquid surface since the diameter of the oil discharge pipe inlet 369 is relatively large. Thus, this example provides an automated oil discharge device which, if applied to a large-sized vessel, can function satisfactorily without being affected by a tilt of the vessel. An automated discharge device using an electric sensor is known; however, it practically presents malfunction problems when used with a creamy oil matter having a larger content of water. This is the reason why the separator according to the present invention is developed.

As mentioned above, the above separator can automatically separate and discharge oil matters from oil-containing water without being affected by tilting and rolling movements of a vessel to which it is attached, and can be best-suited for use in shipping with good performance, thus meeting the above mentioned IMCO requirements.

Further, it is preferable that a coalescer is provided in the reservoir 362 and/or the floating tank 332 to prompt the oil particles to float in a shortest possible time. As shown in Fig. 16, there is provided a coalescer 370 in the floating tank 332, which coalescer includes a plurality of slanting plates 371 maintaining predetermined spacings. It is known in general that, the larger the diameters of oil particles dispersed in the water are, the quicker those particles float on the water surface. If the tank 332 is partitioned by the slanting plates, the particles reach the plates in a shorter time that they float onto the water surface where no coalescer is provided. Thus, even if the diameters of the particles are small, they reach the slanting plates one after another to coalesce each other to become larger-sized oil particles. Those oil particles ascend along the plates 371 to reach the liquid surface. This is known as coalescence effect. The coalescer may be provided not only in the form of the example shown in Fig. 16 but may be provided in the reservoir 362. Moreover if it is provided in the floating tank 144, 244 or 232 in the embodiments of Figs. 1, 9, and 11, the efficiency of oil-water separation of the entire system shows remarkable improvement.

Referring to Fig. 17, there is shown a flow chart of another embodiment, wherein reference numeral 421 stands for an element, 414 a granulator including therein element 421, 451 an oil extractor equipped with a driving an extraction tank, 426 changeover valve, 457 a water supply pipe, 458 a discharge pump, 412 a main pump, 444 a first floating tank, 432 a second floating tank, and 459 an outomated oil matter discharge device.

A feed of oil-containing water is passed through a pretreatment device such as a strainer and the like, and pumped into the granulator 414 having element 421 via the pump 412, the first floating tank 444 and the changeover valve 426.

Fig. 18 is a longitudinal section of the granulator 414. The granulator 414 includes a granulation cylinder 415 provided at its lower portion with a middle flooring 417 to form a passage chamber 418. An opening 419 is formed in the central portion of the flooring 417 over which is mounted an element chamber 420. The chamber 420 is incorporated with the granulation element including a porous material 424 on which is applied a specific granulation layer capable of absorbing and transmitting water therethrough. The element 421 which takes a horizontal position may be identical in construction with the widely available element. More specifically, the porous material 424 treated as mentioned above is corniced around a cylindrical member 423 having a number of through holes 422, at the center. The member 423 is positioned in alignment with the opening 419 in the flooring 417 and fixed thereon. There is then left an appropriate space 433 around and above the element 421.

The granulator 414 is also formed with inlet (outlet) pipes 427a, 429b, 427b in communication with the changeover valve 426. The mechanism 451 for extracting oil matters built up in the granulator 414 is connected with the granulator 414 with an inlet (outlet) pipe 429b. The oil matters are extracted in the upper portion of the tank 456, and the water from which oil matters have been separated in the tank 456 is returned to the next granulator 414 or the changeover valve 426 via the pipe 429c or 427b. The oil-containing water fed by the pump 412 is passed through the changeover valve 426 as indicated by the solid lines in Figs. 18 and 19, enters the passage chamber 418, permeates through the porous material 424 of the element 421, and is forcibly fed into the extraction tank 456. The oil matters extracted in the upper portion of the mechanism 451 is extracted via the extraction valve 455, and is supplied into the second floating tank 432. The water treated is returned to the changeover valve 426 via the pipe 427b, and forcibly supplied into the second floating tank 432 via the discharge pipe 431.

As the oil-containing water enters the granulator 414 and permeates through the element 421, a dispersion with fine oil granules

dispersed, to say nothing of the granulated oil matter, is positively collected owing to the oil-absorbing function under the action of the porous material 424 on which is applied the specific layer capable of separating oil from water due to its water-transmitting and -absorbing properties. The thus collected oil matter grows into a larger granule which is spontaneously floatable, and is separated out due to floatage as well as the oil-separating function provided by the (oil-repelling) gel layer on the porous material 424. With the element 421 having such a unique function, it has now been found that oil drops in the emulsion form can grow into a larger granule and be separated off, despite the fact that they have been considered unable to be isolated.

The oil matters granulated by the granulator 414 is accumulated to the upper portion of the tank 456, and positively extracted as occasion arises or at regular intervals by the extraction valve 455 of the mechanism 451 operable by the driving mechanism 452. The oil matters are then supplied into the second floating tank 432. Especially where a plurality of granulator 414 are arranged in multistage manner, an extractor is provided for each granulator. With this arrangement, the oil matter having a high oil content and/or a high oil concentration serves to reduce a load applied on the surface layer of element 421 in the next granulator 414 in the course of granulation, thus making marked improvements in the efficiency and durability of granulators 414.

It has been found that the provision of extractors 451 results in considerable reductions in the number of granulators 414. In general, the oil-containing water is contaminated with many kinds of impurities (SS) such as suspended matters and fine dust. For this reason, clogging of the element 421 takes place during use with resultant lowering of the efficiency thereof. In such a case, most of conventional systems were shut down to wash the element for the purpose of recovering their function, leading to a reduction of processing ability to a marked degree. The present invention offers a skillful solution to this problem, and enables the apparatus to be operated in a continuous manner without shutdown, while the element is washed.

In the present invention, the direction of material flow is changed by the operation of the changeover valve 426 to cause reversal of the flow before clogging of the element 421 occurs. The manipulation of the changeover valve causes the flow of oil-containing water to be reversed as shown by solid line arrows and dotted line arrows in Fig. 18. This reversal flow causes removal of SS deposited onto the face of the porous material 424 opposite to the flow. Moreover, oil granules of smaller and larger sizes which are deposited onto this face will also be removed and separated by this reversal of the flow. Both sides of the element serve equally for the granulation and growth of oil drops notwithstanding the direction of the flow of oil-containing water. The operation of the changeover valve 426 may be performed manually independence upon the given duration of operation, the given throughput and the increase in feed pressures. Alternatively, the changeover valve may be automatically operated in coopearation with a timer, a flow meter or a feed water pressure gauge.

In the alternating operation according to the present invention wherein the direction of material flow is altered, successful removal of oil granules from the element is attained with attendant pressure loss amounting to as low as about 0.1 to 0.4 Kg/cm^2, so that the element 421 is of high water permeability. Such a high water permeability, coupled to the extraction of oil matters, enables the element 421 to granulate an oil matter having a high viscosity at lower pressures. This offers one of the characteristic features of the present invention.

In the oil-water separator systems, it is generally said that the higher the feed pressure, the lower will be the separation efficiency because of fine granulation of oil. In the present invention, however, a lower pressure can be applied as discussed above, so that such fine granulation of oil is avoided. This has a synergistic effect that assures satisfactory granulation of oil drops in the present invention. These considerations lead to the realization of the present invention.

While the foregoing explanation implies a case where a plurality of element cylinders 414 are arranged in multistage manner, whether the apparatus is of a single stage or multistage arrangement may be dependent upon the throughput of oil-containing water, and the concentration and viscosity of an oil matter. Alternatively, it may be possible to operate part of the multistage apparatus under normal conditions, which apparatus can be operated in its entirety only under severer conditions.

Further floating tank 432 may be provided on top of the automatic oil discharge section 459, which is shown by any of the FIGS. 14 to 16.

Referring to Fig. 19 which schematically shows the method of the present invention, a feed of oil-containing water is fed into a changeover valve 526 via a first floating separation tank 544. Crude oil matters are eliminated by an oil matter-removing device 559 in the first floating separation tank 544. A flow direction changeover mechansm 577 for the oil-containing water comprises a motor 575 and a changeover valve 526 for effecting flow direction changeover of the oil-containing water. Such changeover way be effected by reversal of the predetermin...

ment column 523 by putting the valve in operable association with a mechanism 576 for preventing a build-up of oil matters. Referring to the case where a feed of oil-containing water is guided in the direction as indicated by the solid lines in Fig. 1, it is fed into a passage chamber 518 in the element column 523 having therein an element 521, and directed into an oil matter extractor 551 via the element 521 and an element chamber 520.

Fig. 20 is a longitudinal section of the element column 523, and Fig. 21 is a partial cross-section of the element 521, illustrative of the flow direction of oil-containing water. The granulation element column 523 includes the granulation element 521 comprising a porous material on which are applied a layer capable of absorbing and transmitting water therethrough and a layer capable of resisting and repelling oil. The element 521 may be identical in construction with the widely available element. More preferably, however, the element is of the corrugated cardboard flute type or similar type having a number of elongated passages 542. The elongated passages 542 as shown in Fig. 20 have one ends 539 opened and the other ends 542 closed as depicted in Figs. 20 to 21, so that the oil-containing water permeates through adjacent passages 542 by way of the above-mentioned specific layers. The oil matter extractor 551 comprises a motor 552, an extraction valve 555 and an extraction column 556, and is operated manually or automatically depending upon operating time or pressure to extract the oil matters which are then fed into a second floating separation tank 532.

The water thus treated by extraction is passed into the next element column 523. It is noted that, with the element column 523 of a single stage arrangement, the water treated returns from the extraction column 556 to the changeover valve 526. This is true of the case where the oil-containing water is passed in the direction as indicated by the dotted lines in Fig. 19 by changeover of the valve 526 and opposite to that as indicated by the solid lines. The treated water leaving the final stage extraction column 556 returns to the changeover valve 526, from which it is fed into the second floating tank 532.

As the oil containing water permeates through of the unique layer of the element 521, dispersion with fine oil granules having a size of at most 1 micron being dispersed, to say nothing of the granulated oil matter, is positively collected owing to the oil-absorbing function under the action of the porous material on which is applied the specific layer capable of separating oil from water due to its water-transmitting and -absorbing properties. The thus collected oil matter grows into a larger oil granule which is spontaneously floa- well as the oil-separating function provided by the (oil-repelling) gel layer on the porous material. With the element 521 having such a unique function, it has now been found that oil drops in the emulsion form can grow into a larger granule and be separated off, despite the fact that they have been considered unable to be isolated.

The oil matter reaching the top of the element column 523 is positively extracted by an extractor 551. Especially where a plurality of element cylinders 523 are arranged in multistage manner, an extractor is provided for each granulator. With this arrangement, the oil matter having a high oil content and/or a high oil concentration serves to reduce a load applied on the surface layer of element 521 in the next element 521 in the course of granulation, thus making marked improvements in the efficiency and durability of granulators.

The embodiment is further characterized in that the mechanism 576 is provided for the prevention of a build-up of the oil matters granulated in the element 521 and element column 523. Referring to the embodiment of Fig. 19, the granulation element 523 is inclined at an angle A_1, and is disposed for pivotal movement that is caused by the motor 575 such that open ends of the elongated passages 542 normally take raised positions. With the aforesaid angle is set A_1, a flow of oil-cotaining water is passed in the direction indicated by the solid lines. For reversal of the flow, the column is inclined at an angle A_2.

As mentioned above, reversal of the angle of tilt of the element column cuases the oil matters granulated in the elongated passages 542 of element 521 and the element column 523 to ascend and reach the inclined upper extractor 551 without discontinuities, thus resulting in considerable increases in the efficiency of separation and removal of oil matters.

It has been found that the provision of extractors 551 results in considerable reductions in the number of element columns 523. In general, the oil-containing water is contaminated with many kinds of contaminants or impurities (SS) such as suspended matters and fine dust. For this reason, clogging of the element 521 takes place during use with resultant lowering of the efficiency thereof. In such a case, most of conventional systems were shut down to wash the element for the purpose of recovering their function, leading to a reduction of processing ability to a marked degree. The present invention offers a skillful solution to this problem, and enables the apparatus to be operated in a continuous manner without shutdown, while the element is washed.

It has now been confirmed that the above-mentioned two requirements, i.e., prevention of accumulation of the oil matter in both the

and changeover of material flow, have a synergistic effect in maintaining the efficiency of the apparatus for a very extended period of time even when it is used with an oil matter a high viscosity.

In the present invention, the direction of material flow is changed by the operation of the changeover valve 526 to cause reversal of the flow before clogging of the element 521 occurs. The manipulation of the changeover valve causes the flow of oil-containing water to be reversed as shown by solid line arrows and dotted line arrows in Fig. 19. This reversal flow causes removal of SS deposited onto the face of the porous material 524 opposite to the flow. Moreover, oil granules of smaller and larger sizes which are deposited onto this face will also be removed and separated by this reversal of the flow. Both sides of the element 521 serve equally for the granulation and growth of oil drops notwithstanding the direction of the flow of oil-containing water. The operation of the changeover valve 526 maybe performed manually independence upon the given duration of operation, the given throughput and the increase in feed pressures. Alternatively, the changeover valve may be automatically operated in cooperation with a timer, a flow meter or a feed water pressure gauge.

In the alternating operation according to the present invention wherein the direction of material flow is altered, successful removal of oil granules from the element is attained with attendant pressure loss amounting to as low as about 0.1 to 0.4 Kg/cm^2, so that the element 521 is of high water permeability. Such a high water permeability, coupled to the forced extractor 551 for oil matters, enables the element 521 to granulate an oil matter having a high viscosity at low pressures. This offers one of the characteristic features of the present invention.

In the oil-water separator systems, it is generally said that the higher the feed pressure, the lower will be the separation efficiency because of fine granulation of oil. In the present invention, however, a lower pressure can be applied as discussed above, so that such fine granulation of oil is avoided. This has a synergistic effect that assures satisfactory granulation of oil drops in the present invention. These considerations leads to the realization of the present invention.

While the foregoing explanation implies a case where a plurality of element column 523 are arranged in multistage manner, whether the apparatus is of a single stage or multistage arrangement may be dependent upon the throughput of oil-containing water, and the concentration and viscosity of an oil matter. Alternatively, it may be possible to operate part of the multistage apparatus under normal conditions, which apparatus can be operated

This system is not only adequate for the batchwise processing of oil-containing water, but also demonstrates an especially superior effect in the processing of emulsified finely divided oil-containing water including oil particles made smaller than 1 μ by the effect of a surface active agent, which could not be attained by conventional technique. For example, it has been confirmed by experiment that the water containing 250,000 ppm of light oil can be processed to less than 5 ppm under the test specification of ship's equipment in accordance with the IMCO-Convention, and that 5 ppm determined as the limit for industrial waste water for environmental protection can perfectly be attained.

This invention has especially novel features in permitting separation of not only the finely divided oil but also the emulsified oil matter, because of the formation of the specific layer mainly consists of water insoluble hydrousgel layer having an oil separation function as well as an oil-resisting and oil-repelling function.

CLAIMS

1. A method for oil-water separation by granulation comprising the steps of:

forming a granulation layer having oil-resisting and repelling properties as well as water transmitting and absorbing properties on at least one surface of a porous material by forming thereon a water-insoluble hydrousgel layer while maintaining a porous nature of the material to obtain a granulation element; and

subjecting said granulation element to a flow of an oil-containing water to granulate an oil matter contained therein on the granulation element, said flow being one of two opposite directions.

2. A method according to claim 1, wherein said subjecting step includes a step of passing said water through the granulation element alternately from each side thereof to the other.

3. A method according to claim 1, further including prior to said subjecting step a step of removing an oil matter separated due to coalescence effect from said oil-containing water in a floating tank.

4. A method according to claim 3, wherein said subjecting step and said removing step are performed alternately.

5. A method according to claim 1 or 2, further including a step of extract removing the granulated oil matter.

6. A method according to any one of the claims 1, 2, and 5, wherein said subjecting step is performed in plural consecutive stages.

7. A method according to any one of the claims 1, 2, 3, and 5, wherein said removed oil matter is subjected to a further float separation step to discharge the separated oil matter.

8. An apparatus for oil-water separation

a granulation element having a granulation layer having oil-resisting and repelling properties, said element being formed by forming a water-insoluble hydrausgel on at least one side of a porous material while maintaining a porous nature thereof;

a casing to accommodate said granulation element; and

inlet and outlet means provided in said casing for an oil-containing water flow in two opposite directions.

9. An apparatus according to claim 8, further including a floating tank to receive an oil-containing water prior to its flow into said casing.

10. An apparatus according to claim 9, further including

a reservoir provided on top of said floating tank to receive the oil-containing water from said floating tank;

a water discharge pipe having an inlet portion thereof at its lower portion and extending vertically from the inlet portion up to a predetermined level below the water surface;

a water discharge pipe sleeve enclosing the water pipe discharge pipe from the oil-containing water and extending higher than the water surface, said sleeve being adapted to discharge the water separated from oil outside the reservoir; and

an oil discharge pipe provided to enclose the water discharge pipe sleeve and having an inlet port slightly below the liquid level and above the inlet port of the water discharge pipe such that the oil separated from the water is discharged outside of the reservoir by use of a difference of levels due to that of specific gravities of the oil and the water.

11. An apparatus according to claim 10, further including coalescer means within at least one of the said floating tank and said reservoir.

12. An apparatus according to claim 8, wherein said granulation element is in the form of a corrugated cardboard flute having a plurality of adjoining elongated passages.

13. An apparatus according to claim 12, wherein said adjoining elongated passages have ends thereof close and open alternately.

14. An apparatus according to any one of the claims 8, 12 and 13, further including means for extracting a built-up oil in said casing.

15. An apparatus according to any one of the claims 8, 12 and 14, wherein said inlet and outlet means is adapted to control the oil flow alternately in the two opposite directions.

16. An apparatus according to claim 14 or 15, further including

a floating tank to store the concentrated oil-containing water extracted by said extracting means;

a reservoir provided on top of the floating tank and into which said concentrated oil-containing tank;

a water discharge pipe having an inlet portion thereof at its lower portion and extending vertically from the inlet portion up to a predetermined level below the water surface;

a water discharge pipe sleeve enclosing the water pipe discharge pipe from the oil-containing water and extending higher than the water surface, said sleeve being adapted to discharge the water separated from oil outside the reservoir; and

an oil discharge pipe provided to enclose the water discharge pipe sleeve and having an inlet port slightly below the liquid level and above the inlet port of the water discharge pipe such that the oil separated from the water is discharged outside of the reservoir by use of a difference of levels due to that of specific gravities of the oil and the water.

17. An apparatus according to claim 16, further including coalescer means within at least one of the said floating tank and said reservoir.

18. An apparatus according to claim 16, wherein intermediate portions of said water discharge pipe, said water discharge pipe sleeve, and said oil discharge pipe are flexible, said water discharge pipe sleeve or said oil discharge pipe having plural floating rod radially extending therefrom, said floating rods carrying a ring-shaped float at their intermediate portions and an L-shaped lever pivotally at an apex thereof on an end of each floating rod, an inside end of the lever carrying a balance weight and an outside end of the same carrying a guide.

19. An apparatus according to claim 8, or 12, wherein said granulation element takes a horizontal position.

20. An apparatus according to claim 13, wherein the inlet and outlet means provides an alternate flow of the oil-containing water in two opposite directions, the granulation element being adapted for pivotal movement such that open ends of the elongated passages normally take raised positions.

21. An apparatus for oil-water separation by granulation comprising:

a plurality of granulation elements each having a granulation layer having an oil-resisting and repelling properties, said element being formed by forming water-insoluble hydrousgel on at least one side of a porous material while maintaining a porous nature thereof;

a casing to accommodate each granulation element; and

inlet and outlet means provided in said casing for an oil-containing water flow in two opposite direction.

22. An apparatus according to claim 21, further including means for extracting a built-up oil in said casing.

23. An apparatus according to claim 22,

to control the oil flow alternately in the two opposite directions.

24. An apparatus according to claim 8 or 21, further including a crude water tank to store the oil-containing water which is to be admitted into the casing prior to thereof and suction means for sucking high oil concentration part at the surface of the oil-containing water stored in said crude water tank.

25. An apparatus according to claim 24, wherein said suction means includes an outer cylinder having a take-out tube at a bottom thereof and positioned below the liquid level and a weir cylinder provided vertically movabily within the outer cylinder and adapted to keep a brim thereof positioned slightly below the liquid level and providing communication with said take-out tube.

26. An apparatus according to claim 25, wherein said brim is of saw-edge configuration.

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